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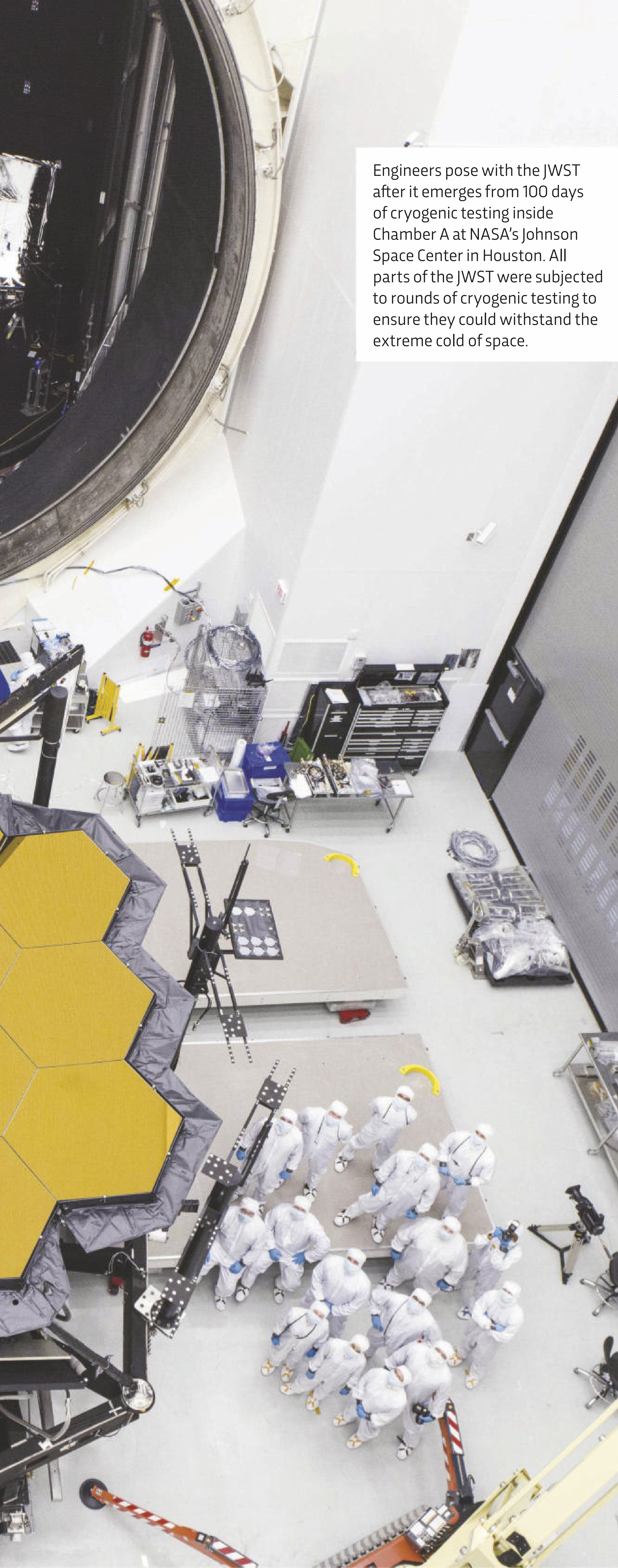
EYE IN THE SKY

AS THE JAMES WEBB SPACE TELESCOPE READIES FOR ITS LAUNCH LATER THIS YEAR, WE TAKE A LOOK AT HOW THIS HUBBLE SUCCESSOR WILL ECLIPSE ITS PREDECESSOR

WORDS: NISHA BEERJERAZ-HOYLE
PHOTOS: NASA/GODDARD SPACE FLIGHT CENTER



Engineers pose with the JWST after it emerges from 100 days of cryogenic testing inside Chamber A at NASA's Johnson Space Center in Houston. All parts of the JWST were subjected to rounds of cryogenic testing to ensure they could withstand the extreme cold of space.

After nearly 20 years of development and 16 launch delays, the James Webb Space Telescope (JWST) is almost ready. Set to launch on 31 October 2021, the largest space observatory ever built is set to revolutionise our understanding of the cosmos and help solve some of the Universe's greatest mysteries.

It hasn't been an easy journey. First conceived 30 years ago as the successor to the Hubble Space Telescope, the 'Next Generation Telescope' as the JWST was first known, has survived threats of cancellation, changes of leadership and numerous postponements. Expected to cost $10bn (£7.2bn approx), the JWST (named after NASA's second administrator James E Webb) is the sixth most expensive space mission of all time. And it's not surprising: the JWST is brimming with innovation and complexity, is the product of a large international collaboration between the US, European and Canadian space agencies, and is often described as one of NASA's biggest and boldest undertakings, one that will contribute unparalleled value to science and technology.

LOOKING DEEPER

For over 25 years, Hubble has graced us with beautiful images of the 13.8-billion-year-old Universe, capturing light emitted just 500 million years after the Big Bang. JWST's infrared 'eyes' will be able to peer even further into the Universe's early history, back to when the first stars and galaxies were born.

The telescope will also venture further from Earth than its predecessor. While Hubble follows a close orbit, around 550km above Earth, the JWST will float up to 1.5 million kilometres from us and orbit the Sun. It will cast its gaze on the likes of Mars, comets, dwarf planets and exoplanets, to teach us more about how planets and solar systems form.

Hubble isn't the only telescope the JWST will surpass though; it'll eclipse another great space observatory too: Spitzer (launched in 2003 and retired in early 2020). As Naomi Rowe-Gurney, a planetary scientist at the University of Leicester explains: "Data from Spitzer has shown some really unexpected behaviour happening on Uranus and we have no idea what's causing it. The only way we

LEFT Chamber A, the world's largest thermal vacuum chamber at NASA's Johnson Space Center in Houston, was made famous by testing spacecraft used for the Apollo missions. It was remodelled by technicians to accommodate the JWST.

can find out is by using the JWST's power and infrared capabilities."

The JWST will also deepen our knowledge of exoplanets. "We're finding more exoplanets with the same masses as our ice giants, Uranus and Neptune. Because we don't know much about the ice giants in our Solar System, we can't understand those in other planetary systems. The JWST is definitely going to change how we view our Solar System," says Rowe-Gurney.

WEBB DESIGN

Looking at the telescope towering over engineers at NASA's Johnson Space Center in Houston, Texas, you can see why it's a game-changer. The JWST's primary mirror is a thing of beauty. Its honeycomb structure is an impressive 6.5m in diameter and made up of 18 adjustable, gold-plated beryllium segments. Compared to Hubble, the JWST has six times the light-collecting area and a much wider field of view (roughly 15 times larger). Yet, at 6,500kg, it's almost half the mass.

The light captured by the optics will be analysed by the four science instruments on board – collectively known as the Integrated Science Instrument Module (ISIM). The optical mechanisms need to be kept below -223°C to maximise the chances of detecting faint traces of infrared light. The Mid-Infrared Instrument (MIRI) requires an even lower temperature of -266°C, barely above absolute zero. To prevent the Sun's heat and light from interfering with its observations, the JWST is equipped with cryocoolers and a five-layer, tennis-court-sized sunshield.

Despite its huge size, the entire observatory must fold down to fit inside an Ariane 5 rocket's nose cone. Once deployed, the JWST will unfold itself, cool down and calibrate. Mission success hinges on flawless execution

"COMPARED TO HUBBLE, THE JWST HAS SIX TIMES THE LIGHT-COLLECTING AREA AND A MUCH WIDER FIELD OF VIEW"

of this sequence, one which has never before been attempted in space.

To add even more jeopardy, the JWST will be beyond the reach of manned repair missions, unlike Hubble, which needed five. This is why testing has been of the highest importance for the mission team every step of the way.

But, according to Paul Geithner, JWST's technical deputy project manager, assessing an observatory designed to deploy and operate in space is no easy feat. "We could not test the entire observatory as one complete entity in a simulated space environment – it's a departure from the early days of the space age when you could put an entire spacecraft into a thermal vacuum chamber and test it all at once," he explains. Instead, individual units, built in different parts of the world, were tested before they were brought together and assembled into two 'super-halves', comprising the Optical Telescope element/Integrated Science instrument module (OTIS), and the combined spacecraft bus and sunshield. Each unit was tested in acoustic and vibration chambers that replicated a violent, noisy launch, and also placed into a large freezer, known as 'Chamber A', for months to check they could withstand the freezing temperatures of space.

ABOVE The JWST's sunshield is the largest part of the observatory. The five layers of thin membrane must unfold precisely to provide a thermally stable environment. Here, engineers test a full-sized replica in a clean room at the Northrop Grumman facility in California.

The JWST's 18-segment primary mirror hangs in the clean room at NASA Goddard Space Flight Center. Six of the segments (three on either side) will fold back so the mirror can be stowed in the Ariane 5 rocket upon which the observatory will be launched.

LEFT Small dust particles can greatly affect the science the JWST is able to do, so pristine mirrors are critical. Here engineers practise using carbon dioxide snow to clean a test mirror segment and remove contaminate particulates without scratching the surface.

BELOW LEFT Mirror segments are inspected with torches for any imperfections. They're made from a light material called beryllium, which has been ground and polished, before being coated with a layer of gold only nanometres thick to optimise their infrared reflectivity.

"CUTTING-EDGE ENGINEERING OF NEW SPACEFLIGHT HARDWARE IS A HUMBLING BUSINESS"

There have been some bumps on this long road, such as loose fastening screws found after acoustic and vibration testing in 2016, and, most notably, the sunshield ripping after a test deployment in March 2018. "Cutting-edge engineering of new spaceflight hardware is a humbling business," Geithner reflects.

THE FINAL COUNTDOWN

In August 2019, the two super-halves were combined at a Northrop Grumman facility in California to undergo full integration testing. And in 2020, during the COVID-19 pandemic, the fully assembled JWST accomplished an astounding feat: it passed every single test.

Granted, prior to the testing success the JWST's launch was postponed once again. But this time it was only from March to October 2021 – a reasonable delay considering the team has had to work remotely and in socially distanced shifts, during a critical phase.

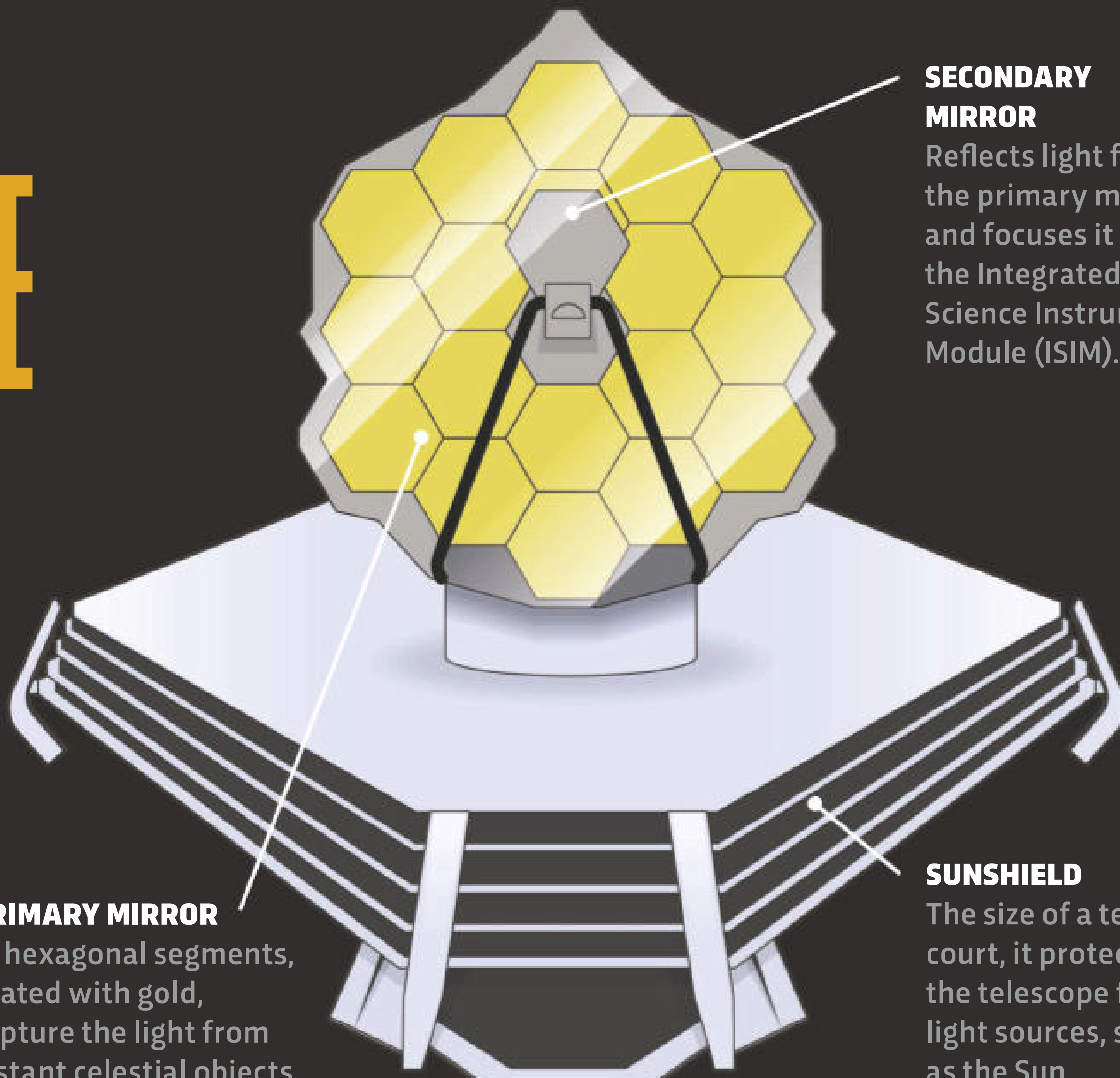
With only months left until the JWST launches from French Guiana, Geithner now has time to reflect on the power of the project so far: "While the JWST is to be a tool of science and has been a daunting engineering challenge, it is, in the end, a human story, a generational project." Indeed, there is no doubt the discoveries it could make will serve generations to come. SF

by NISHA BEERJERAZ-HOYLE

Nisha is a freelance space and astronomy writer.

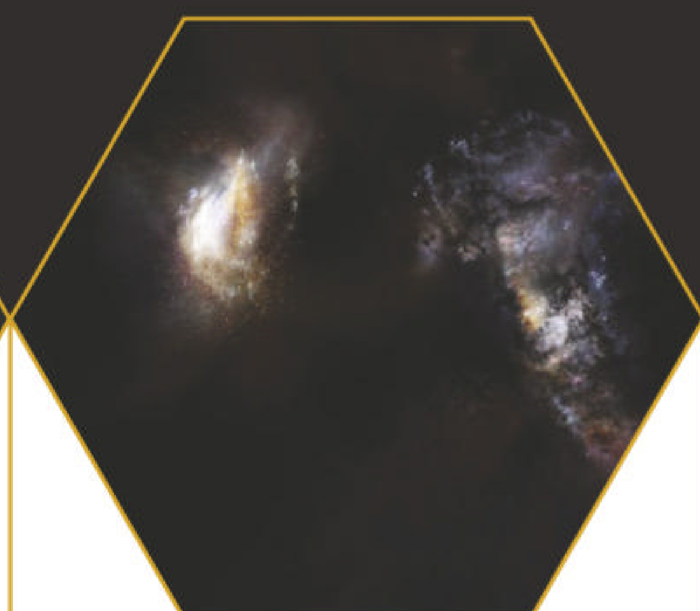
THE TELESCOPE IN FOCUS

THE JAMES WEBB SPACE TELESCOPE WILL IMAGE THE LITTLE KNOWN PLACES IN THE MILKY WAY AND BEYOND. HERE ARE JUST A FEW OF THE THINGS IT HOPES TO SEE AND THE TECH IT WILL USE TO SEE THEM...



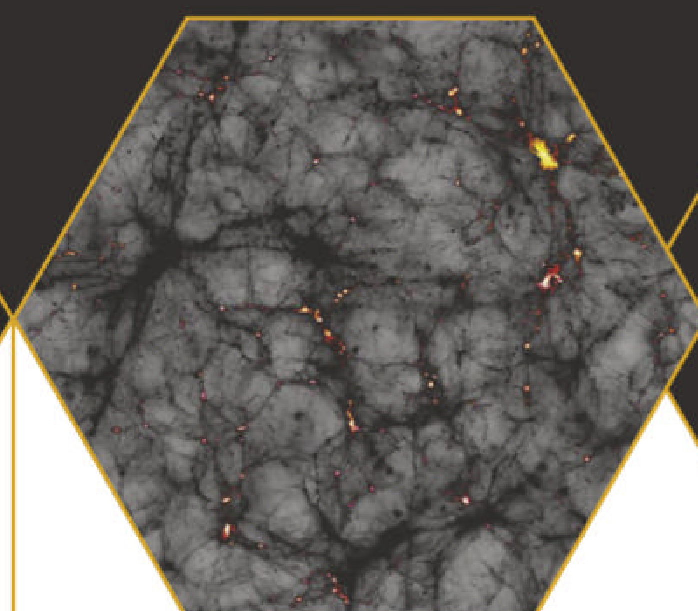
FIRST LIGHT

The JWST will be able to look back to around 200 million years after the Big Bang, when the first stars in the Universe formed. The first stars are thought to have been massive giants made of hydrogen and helium, whose short lives ended in the supernovae that created the heavier elements we detect in younger stars today. To see this period in cosmic history, we need sensitive infrared instruments to detect the faint traces of light that have travelled through space and time to reach us.



ANCIENT GALAXIES

The JWST will also look back to the very first galaxies in the Universe to learn more about their evolution and why there's so much variety in them. Nearly all the spiral and elliptical galaxies that we see today have experienced at least one collision or merger with another local galaxy. Yet older galaxies look entirely different to their modern counterparts – smaller, clumpier, less structured. Examining galaxies can also inform us of the macrostructure of the Universe and how it's organised on a large scale.



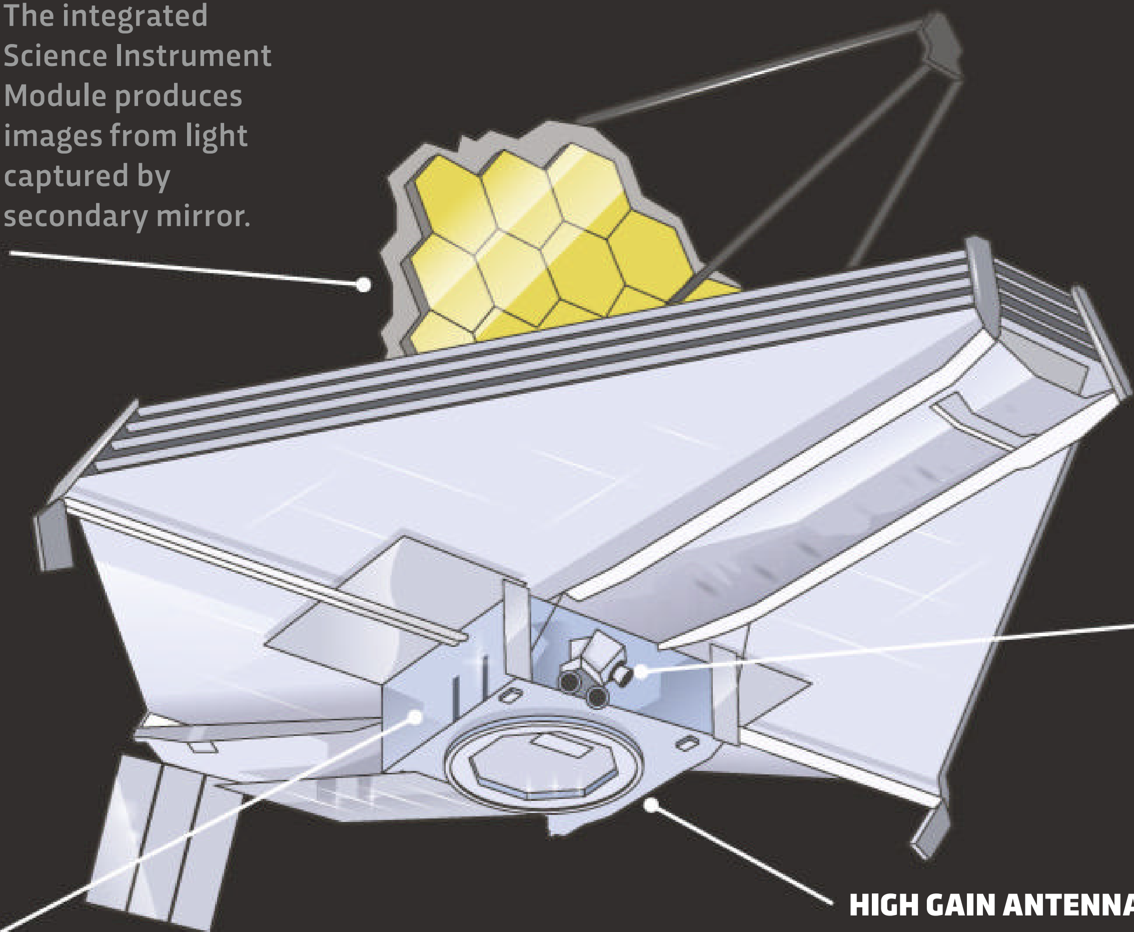
DARK MATTER

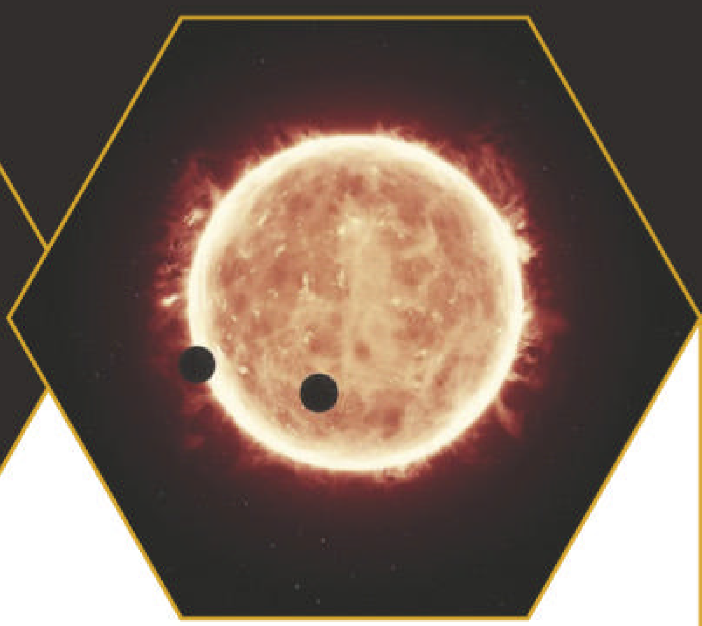
Dark matter is thought to play an important role in the structure of the Universe, accounting for five times the mass of normal, baryonic matter such as atoms and particles. Considered to be the scaffolding for the Universe, we're only able to observe dark matter indirectly by measuring how its gravity affects stars and galaxies. The JWST won't be able to see dark matter, but it will employ gravitational lensing techniques to study the most distant galaxies and look at their rotation for signs that dark matter is at play.

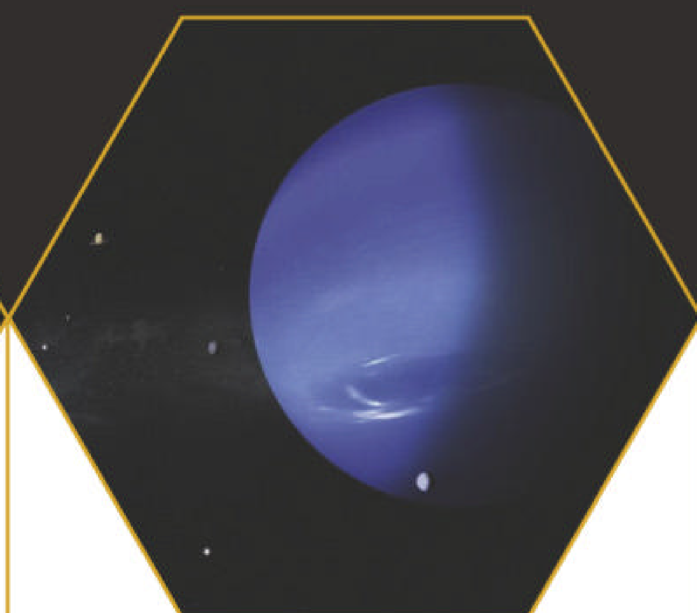
NASA, D BERRY/NRAO, GETTY IMAGES X3 ILLUSTRATION: ACUTE GRAPHICS

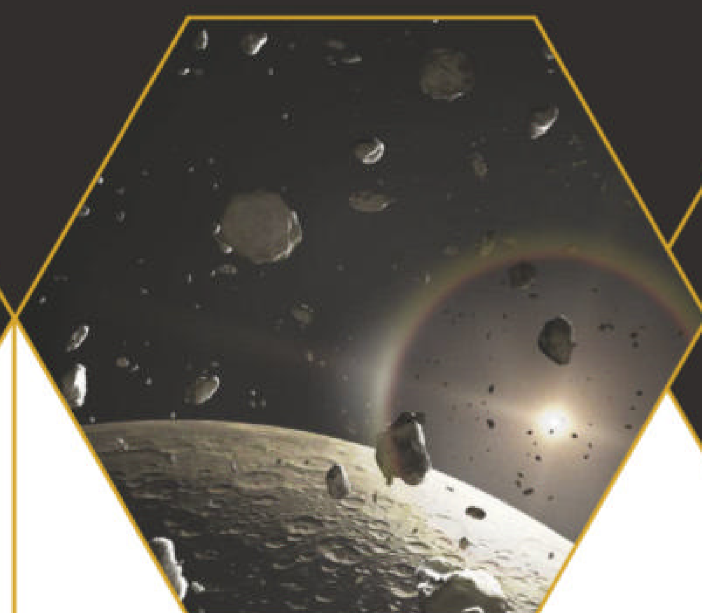
JWST FACT FILE

SIZE: 21 x 14m (sunshield)
LAUNCH MASS: 6,200kg
COST TO BUILD: $10bn
LAUNCH DATE: 31 October 2021
EXPECTED FIRST IMAGES: 2-3 months after launch
COLLABORATORS: NASA, ESA and Canadian Space Agency
MISSION DURATION: 5-10 years
ORBIT: 1.5 million km from Earth









EXOPLANET ATMOSPHERES

The JWST will help answer the big question of whether life exists beyond Earth by studying a variety of exoplanets – planets outside our Solar System. Of particular interest is the TRAPPIST-1 system, where three of its seven planets are in the habitable zone and one may harbour liquid water. The JWST will observe the planet as light from its parent star passes through the planet's atmosphere, revealing its chemical composition and the gases that are present there.

OUR ICE GIANTS

While the JWST's primary science aims lie more in cosmology and star formation, it'll also take a closer look at a couple of familiar objects – our ice giants, Neptune and Uranus. The JWST will map their atmospheric temperatures and chemical composition to see how different they are – not only to each other, but also their gas giant cousins, Jupiter and Saturn. The ice giants are at least 30 times further from the Sun than Earth and are the least understood planets in our Solar System.

PLUTO AND THE KBOs

Dwarf planet Pluto and its fellow Kuiper Belt Objects will also be receiving some observation time. The JWST is powerful enough to study such icy bodies including comets, which are often-pristine leftovers from our Solar System's days of planet formation and could hold clues to Earth's origins. There are no planned missions dedicated to the outer Solar System for years, so new observations and data will play a big part in planning for future planetary missions.